

# **California Air Resources Board**

## **Quantification Methodology for the Department of Transportation Low Carbon Transit Operations Program**

### **Greenhouse Gas Reduction Fund Fiscal Year 2016-17**



**Note:**

Methodologies are updated as new quantification or Program information is available. ARB also accepts public comment on draft versions of methodologies. Please check the ARB Quantification website to download the most recent methodologies and tools and for public comment periods.

<https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/auctionproceeds.htm>

**DRAFT  
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## Section A. Introduction

The goal of California Climate Investments is to reduce greenhouse gas (GHG) emissions and further the purposes of the Global Warming Solutions Act of 2006, known as Assembly Bill (AB) 32. The California Air Resources Board (ARB) is responsible for providing the quantification methodology to estimate the GHG emission reductions and other benefits from projects receiving monies from the Greenhouse Gas Reduction Fund (GGRF). ARB develops these methodologies based on the project types eligible for funding by each administering agency. ARB staff periodically review each quantification methodology to evaluate its effectiveness and update methodologies to make them more robust, user-friendly, and appropriate to the projects being quantified.

For the Department of Transportation's (Caltrans) Low Carbon Transit Operations Program (LCTOP), ARB staff developed this quantification methodology and LCTOP GHG Calculator Tool to provide methods for estimating net GHG emission reductions of each proposed project (Section B), provide instructions for documenting and supporting the estimate (Section C), and outline the process for tracking and reporting GHG and other benefits once a project is funded (Section D).

This methodology is based on the "Methods to Find the Cost-Effectiveness of Funding Air Quality Projects for Evaluating Motor Vehicle Registration Fee Projects and Congestion Mitigation and Air Quality Improvement Projects" (CMAQ Methods) to estimate the reduction in vehicle miles traveled (VMT) and associated GHG emission reductions based on transportation characteristics of the proposed project.

### Tools

The CMAQ Methods are used statewide, are publicly available, and are subject to regular updates to incorporate new information. The CMAQ Methods were developed by ARB and Caltrans, and are used statewide by transportation agencies to evaluate criteria pollutant emission reductions from transportation projects competing for State motor vehicle fee and federal CMAQ funding. The CMAQ Methods were used as the basis for developing the GHG emission reduction estimates for the LCTOP project types. All of the equations and assumptions needed for this quantification method are included in this document and some assumptions have been modified, as necessary. The CMAQ Methods document can be downloaded from <https://www.arb.ca.gov/>.

## Methodology Development

ARB and Caltrans developed this quantification methodology consistent with the guiding implementation principles of California Climate Investments, including ensuring transparency, accountability, and outreach and access for disadvantaged communities, as described in ARB's *Cap-and-Trade Auction Proceeds: Funding Guidelines for Agencies Administering California Climate Investments* (Funding Guidelines).<sup>1</sup> ARB and Caltrans developed this quantification methodology through a public process to estimate the outcomes of proposed projects and track the results of funded projects. The implementing principles ensure that the methodology will:

- Apply at the project-level;
- Provide uniform methods to be applied statewide, and be accessible by all applicants;
- Use existing and proven tools and methods;
- Reflect relationships between mode shifts and corresponding VMT reductions and GHG emissions-reductions that are conservative and supported by empirical literature; and
- Use project-level data, where available and appropriate.

ARB reviewed peer-reviewed literature and tools and consulted with experts, as needed, to determine methods appropriate for the LCTOP project types. ARB also consulted with Caltrans to determine project-level inputs available. The methods were developed to provide estimates that are as accurate as possible with data readily available at the project level.

## Updates

ARB updated this quantification methodology from the previous version.<sup>2</sup> The changes include:

- Updates to the GHG emission factors used in calculating emission reductions;
- A revamp of the LCTOP GHG Calculator<sup>3</sup> Tool to simplify the use of the quantification methodology and allow for project-specific input;
- Modification to allow fuel-specific input (i.e., Carbon Intensity or grid-emission factor);
- Ability to calculate the operation of hybrid vehicles and the purchase of zero-emission buses; and
- Additional definitions and clarity to the text.

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<sup>1</sup> <https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/arb-funding-guidelines-for-ca-climate-investments.pdf>

<sup>2</sup> [LCTOP Quantification Methodology for FY 2015-16, December 2015.](#)

<sup>3</sup> [LCTOP GHG Emission Reduction Calculator for FY 2015-16, December 2015.](#)

## Program Assistance

ARB and Caltrans staff will review the quantification portions of the LCTOP project applications to ensure that the methods described in this document were properly applied to estimate the GHG emission reductions for the proposed project. Applicants should use the following resources for additional questions and comments:

- Applicants are encouraged to check the frequently asked questions (FAQ) page regularly during the application process, will be posted at: <https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/quantification.htm>.
- Questions on this document should be sent to [GGRFProgram@arb.ca.gov](mailto:GGRFProgram@arb.ca.gov).
- For more information on ARB's efforts to support implementation of GGRF investments, see: <https://www.arb.ca.gov/auctionproceeds>.
- Questions pertaining to the LCTOP should be sent to [LCTOPcomments@dot.ca.gov](mailto:LCTOPcomments@dot.ca.gov).

## LCTOP Project Types

Caltrans and ARB developed project types that meet the objectives of LCTOP and for which there are methods to quantify GHG emission reductions. Other project features may be eligible for funding under LCTOP; however, each project requesting GGRF funding must include at least one of the following project types for FY 2016-17 from Table 1.

**Table 1. Eligible Project Types by Category**

<b>Project Type</b>	<b>Description</b>
<b>Capital: Capital Improvements (that increase mode share)</b>	
Install new transit facilities	Install new transit facilities (stops/stations) for local bus, intercity rail, commuter bus or rail service or that connect to bike paths/pedestrian path.
Upgrade transit facilities	Upgrade transit stops/stations (e.g., bike-sharing facilities; bike racks/lockers; covered benches; energy efficient lighting) to support active transportation and encourages ridership.
Upgrade transit vehicle(s)	Upgrade transit vehicles (e.g., bicycle racks on buses; bicycle storage on rail cars) to support active transportation and encourage ridership.
<b>Operations: Service Improvements (that increase mode share)</b>	
Transit vouchers	Free or reduced-fare transit vouchers.
Network/fare integration	Network/fare integration (e.g., universal fare card that can be used for multiple transit systems).
<b>Operations: New/Expanded Service</b>	
Implement new transit service	Implement new transit service (new routes/lines).
Expand/Enhance transit service	Expand/Enhance transit service (extend transit routes, extend service hours, increase frequency of service, increase capacity [e.g., add more buses or rail cars to existing routes]).
Provide alternative transit options	Provide alternative transit options that use zero-emission or hybrid vehicles to improve mobility (e.g., vanpooling, shuttles, bikesharing).
<b>Capital: Cleaner Vehicles</b>	
Purchase zero-emission/hybrid vehicle(s).	Rolling stock acquisition. GHG emission reductions achieved by comparing each zero-emission or hybrid purchase against a conventional (diesel) vehicle as the baseline for each project.
Purchase replacement zero-emission/hybrid vehicle(s).	Rolling stock acquisition. Requires a vehicle to be replaced. GHG emission reductions achieved by comparing each zero-emission or hybrid purchase against the replaced (project specific) vehicle as the baseline for each project.

Section B of this quantification methodology details the methods to use based on the project type(s) proposed.

## Section B. Greenhouse Gas Quantification Methodology

### GHG Emission Reduction Quantification Approach

This quantification methodology accounts for GHG emission reductions based on estimated ridership increases and corresponding passenger auto VMT reductions. Some projects may include additional GHG emission reductions such as the replacement of existing transit vehicle or from displaced fuel (e.g. reduced deadhead mileage).

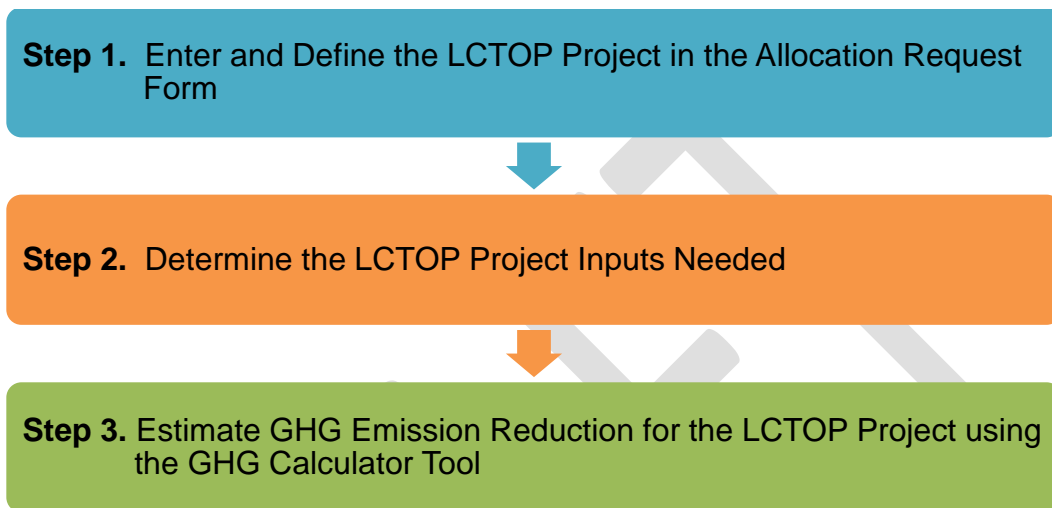
Methods used in the GHG Calculator Tool for estimating the GHG emission reductions by project category are provided in Appendix B. In general, the GHG emission reductions are calculated using the following approaches:

**Table 2. General Approach to GHG Quantification by Project Category**

<b>Capital/Service Improvements</b>
<i>GHG Emission Reductions = GHG Emission Reductions of Displaced Autos</i>
<b>New/Expanded Service</b>
<i>GHG Emission Reductions = GHG Emission Reductions of Displaced Autos – GHG Emissions of New/Expanded Service</i>
<b>Cleaner Vehicles</b>
<i>GHG Emission Reductions = GHG Emissions of Baseline Vehicle – GHG Emissions of New Vehicle</i>
<b>Displaced Fuel</b>
<i>GHG Emission Reductions = GHG Emissions of Displaced Fuel</i>

## Overview

Applicants will follow the steps outlined in Figure 1 to estimate the GHG emission reductions from the proposed project. Detailed instructions for each step are provided on subsequent pages. An example for a New/Expanded Service is included in Appendix A.



**Figure 1. Steps to Estimating GHG Emission Reductions**

**Note:** Applicants with more than one project type must use multiple LCTOP GHG Calculator Tools to quantify the GHG emission reductions from each project.



## Step 1: Determine the LCTOP Project Inputs Needed from the Allocation Request

Applicants must have completed the LCTOP Allocation Request form **Request** tab in order to complete this step. The LCTOP Allocation Request form can be downloaded from <https://www.dot.ca.gov/hq/MassTrans/lctop.html>.

Users should begin with the **Read Me** tab, which contains instructions and prompts users to enter project information. The Project Benefits section in the **Request** tab identifies inputs required by the user, generally requiring project-specific data or assumptions. Input and output fields are color coded:

- **Yellow** fields indicate a selection from a drop-down box or direct user input is required.
- **Orange** fields indicate inputs that may be required based on user entries and the calculation methods.
- **Green** fields indicate calculation fields that are automatically populated based on user entries and the calculation methods.

### LCTOP Allocation Request Form

<b>Project Benefits</b>		
<b>Greenhouse Gas Reductions</b> - Describe qualitatively how this project will reduce greenhouse gas emissions. For example expanded/ enhanced transit service will improve headways thus making transit a more convenient option of transportation thus increasing ridership, reducing Vehicle Miles Traveled (VMT) and reducing GHG.		
<b>Greenhouse Gas Reductions</b> - Please provide quantitative information requested below and explanation/support for the data provided.		
	Value	Explanation
<b>Year 1 (Yr1)</b> - First year of service, or year that capital improvements will be completed.		
<b>Year F (YrF)</b> - Final year that the service is funded or the final the final year of the capital improvements useful life. Yr1 & YrF cannot be the same.		
<b>Project Yr1 Ridership</b> - Estimated annual ridership contributed by the new service or capital improvement in Yr1.		
<b>Project F Yr. Ridership</b> - Estimated annual ridership contributed by the new		

## Step 2: Identify the LCTOP Project Inputs Needed

Table 3 identifies the required data inputs needed to estimate the GHG emission reductions for proposed projects with the LCTOP GHG Calculator Tool. Calculator tool inputs in **orange** must match inputs from the LCTOP Allocation Request form.

**Table 3. Required GHG Calculator Tab Inputs by Project Category**

Input Fields	Capital/Service Improvements	New Service	Cleaner Vehicles
Project Classification	✓	✓	✓
Project Type	✓	✓	✓
Service Type	✓	✓	✓
Region	✓	✓	✓
Subregion	✓	✓	✓
Year 1(Yr1)	✓	✓	✓
Year F(YrF)	✓	✓	✓
Project Yr1 Ridership	✓	✓	
Project YrF Ridership	✓	✓	
Adjustment Factor (A)	✓	✓	
Trip Length (L)	✓	✓	
Vehicle Type		✓	✓
Hybrid Vehicle		✓	✓
Fuel Type		✓	✓
Project Specific Emission Factor		Optional	Optional
Model Year		✓	✓
Annual VMT		✓	✓
Annual Fuel		Optional	Optional
Additional Benefits: Displaced Emissions	Optional: Displaced Fuel	Optional: Displaced Fuel	Optional: Vehicle Replacement
Fuel Type	✓	✓	✓
Model Year			✓
Annual VMT			✓
Annual Fuel	✓	✓	Optional
FY 2016-17 LCTOP Funds Requested	✓	✓	✓
Total LCTOP Funds Requested	✓	✓	✓
Total GGRF Funds Requested	✓	✓	✓

## Step 3: Estimate GHG Emission Reduction for the LCTOP Project using the GHG Calculator Tool

Applicants must use the LCTOP GHG Calculator Tool to estimate GHG emission reductions associated with proposed LCTOP-funded projects. The LCTOP GHG Calculator Tool can be downloaded from:

<https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/quantification.htm>

Users should begin with the **Read Me** tab, which contains instructions to estimate GHG emission reductions. The **GHG Calculator** tab identifies inputs required by the user, generally requiring project-specific data or assumptions. Key terms are defined under the **Description** column and are described with respect to project category and project type. Input and output fields are color coded:

- **Yellow** fields indicate a selection from a drop-down box or direct user input is required.
- **Orange** fields indicate inputs that must match user entries from the Allocation Request form, if applicable.
- **Red** fields indicate an optional direct user input; additional documentation is required to support entry.
- **Green** fields indicate calculation fields that are automatically populated based on user entries and the calculation methods.

*Helpful tips to provide clarification or suggested inputs may appear when input cells are selected.*

### LCTOP GHG Calculator Tool

Project Name:		Contact Name:	
Lead Agency:		Contact Phone #:	
Date Completed:		Contact Email:	
Project ID:			

	Applicant must input if required		Calculated field; no input required
	Required input from Allocation Request form		Applicant must submit additional documentation

Applicant must input required fields from top down (i.e., first Project Category, then Project Type, etc.).  
 Required fields and descriptions are dependent on the inputs selected or entered.  
 User tips to provide clarification or suggested inputs may appear when input cells are selected.

Inputs	Required	Description
This section is used to determine the GHG emission reduction method and emission factors to apply.		
Project Category	Yes	Enter the project category that best represents the proposed project type; see <b>Required Fields by Category</b> . If applying for more than one project type, then the agency must submit multiple Allocation Requests and GHG Calculator tools.
Project Type	Yes	
Region	Yes	The region that best encompassed the geographic location for the proposed project type.
Subregion	Yes	
Year 1 (Yr1)	Yes	
Year F (YrF)	Yes	
Useful Life	Calculated	

## Project Summary

The **Summary** tab calculates and displays the annual and total auto VMT displaced and GHG emission reductions as well as the estimated GHG emission reductions per LCTOP GGRF dollar and per total GGRF dollar requested, as described below. Key terms are defined in the LCTOP GHG Calculator Tool under the **Description** column.

- **Total Project GHG Emission Reductions** is equal to the sum total of each of the GHG emission reductions calculated in Section B and are automatically summed in the LCTOP GHG Calculator Tool in the **Summary** tab.
- **LCTOP GHG Emission Reductions** is equal to the Total Project GHG Emission Reduction prorated as:

$$\text{LCTOP GHG Emission Reductions} = \frac{\text{Total Project GHG Emission Reductions} * \left( \frac{\text{Total LCTOP GGRF Funds Requested} (\$)}{\text{Total GGRF Funds Requested} (\$)} \right)}{1}$$

Applicants should enter the Total LCTOP GGRF Funds Requested (\$) and Total GGRF Funds Requested (\$) into the LCTOP GHG Calculator Tool for all project features.

The Total LCTOP GGRF Funds Requested (\$) is equal to the amount of FY 2016-17 LCTOP dollars the applicant is requesting from Caltrans, plus all LCTOP dollars from Caltrans that have previously been awarded to the same project and any future LCTOP dollars that the project plans to apply for.

The Total GGRF Funds Requested (\$) is equal to the Total LCTOP Funds Requested (\$), plus all GGRF dollars that have previously been awarded to the same project and any other GGRF dollars that the project has or plans to apply for. For a list of GGRF funded programs, go to:

<https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/ggrfprogrampage.htm>.

If no other GGRF funds have been requested, the Total GGRF Funds Requested (\$) will be the same amount as the Total LCTOP GGRF Funds Requested. The LCTOP GHG Calculator Tool; will provide the Total LCTOP GHG Emission Reductions.

- **LCTOP GHG Emission Reductions per Dollars of LCTOP GGRF Funds Requested** is calculated as:

$$\frac{\text{LCTOP GHG Emission Reductions (MTCO}_2\text{e)}}{\text{Total LCTOP GGRF Funds Requested} (\$)}$$

The LCTOP GHG calculator will provide the LCTOP GHG Emission Reductions per LCTOP GGRF Funds Requested.

- **Total Project GHG Emission Reductions per Dollars of GGRF Funds Requested** is calculated as:

$$\frac{\text{Total Project GHG Emission Reductions (MTCO}_2\text{e)}}{\text{Total GGRF Funds Requested ($)}}$$

The LCTOP GHG calculator will provide the Total Project GHG Emission Reductions per GGRF Funds Requested.

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## Section C. Documentation

In addition to LCTOP application requirements, ARB requires each project applying for LCTOP funding to document results from the use of this quantification methodology, including supporting materials to verify the accuracy of project-specific inputs.

Applicants are required to provide electronic documentation that is complete and sufficient to allow the calculations to be reviewed and replicated. Paper copies of supporting materials must be available upon request by Caltrans staff.

The following checklist is provided as a guide to applicants; additional data and/or information may be necessary to support project-specific input assumptions.

	Documentation Description	Completed
1.	Project description, including excerpts or specific references to the location in the LCTOP allocation request form of the project information necessary to complete the applicable portions of the quantification methodology	
2.	Populated LCTOP GHG Calculator Tool file (in .xlsm) with worksheets applicable to the project populated (ensure that the GHG emission reduction and GHG emission reduction/GGRF \$ requested fields in the summary worksheet contain calculated values)	
3.	If the Total GGRF funds requested are different than the LCTOP GGRF funds requested, provide an explanation of the other GGRF program(s) where funding is sought, including the fiscal year of the application(s)	
4.	Any other information as necessary and appropriate to substantiate inputs	

## Section D. Reporting after Funding Award

Accountability and transparency are essential elements for all GGRF California Climate Investment projects. As described in ARB's Funding Guidelines, each administering agency is required to track and report on the benefits of the California Climate Investments funded under their program(s). Each project funded by the GGRF is expected to provide a quantifiable GHG emission reduction. The previous sections of this document provide the methods and tools to estimate the GHG emission reduction of a proposed project based on project characteristics and assumptions of expected conditions and activity levels. This section explains the minimum reporting requirements for administering agencies and funding recipients during project implementation, termed Phase 1, and after a project is completed, termed Phase 2. Table 4 below shows the project phases and when reporting is required.

Funding recipients have the obligation to provide, or provide access to, data and information on project outcomes to Caltrans.

It is the responsibility of Caltrans to collect and compile project data from funding recipients, including the GHG emission reduction and information on benefits to disadvantaged communities.

**Table 4. Quantification and Reporting By Project Phase**

	Timeframe	Quantification Methods
<b>Project Selection</b>	Period from solicitation to funding awards. Applicant submits application to Caltrans by due date in solicitation materials.	All applicants use methods in ARB's quantification methodology to estimate the GHG emission reduction of the project.
<b>Phase 1</b>	Covers the period from the beginning of the project until it becomes operational or the initial implementation is completed.	All funded projects use methods in ARB's quantification methodology to update initial estimate of GHG emission reduction, as needed, based on project changes.
<b>Phase 2</b>	Starts after Phase 1 is complete and a project becomes operational.	GHG reduction achieved are quantified and reported for a subset of funded projects.

Phase 1 reporting is required for all LCTOP funded projects. Caltrans will collect and submit data to ARB to satisfy Phase 1 reporting requirements. Funding recipients must report any changes that impact GHG emission reduction estimates (i.e. assumptions or quantitates) to Caltrans prior to project completion.

Phase 2 reporting is required for only a subset of LCTOP projects and is intended to document actual project benefits achieved after the project becomes operational.

Phase 2 data collection and reporting will not be required for every project. Caltrans will be responsible for identifying the subset of individual projects that must complete Phase 2 reporting, identifying who will be responsible for collecting Phase 2 data, and for reporting the required information to ARB. ARB will work with Caltrans to address Phase 2 procedures, including but not limited to:

- The timelines for Phase 2 reporting, i.e., when does Phase 2 reporting begin, how long will Phase 2 reporting be needed.
- As applicable, approaches for determining the subset of projects that need Phase 2 reporting (i.e., how many X projects out of Y total projects are required to have Phase 2 reporting).
- Methods for monitoring or measuring the necessary data to quantify and document achieved GHG reductions and other select project benefits.
- Data to be collected, including data fields needed to support quantification of GHG emission benefits.
- Reporting requirements for transmitting the data to ARB or Caltrans for program transparency and use in reports.

Once the Phase 2 quantification method and data needs are determined, ARB will develop and post the final ARB approved Phase 2 methodology for use in Phase 2 reporting.



## Appendix A. Example Project

### Introduction

The following is a hypothetical project<sup>4</sup> to demonstrate how the FY 2016-17 LCTOP Quantification Methodology would be applied. This hypothetical project does not provide examples of the supporting documentation that is required of actual project applicants.

### Overview of the Proposed Project

The lead agency plans to expand the existing weekday commuter express service by adding four round-trips per day. The proposed project is determined to be best represented by:

- Project category: Operations: New/Expanded Service, and
- Project type: Expand/Enhance transit service

The proposed project operates predominantly within the Sacramento Valley air basin with the following project features:

- First Year (Yr1) of service: 2017
- Final Year (YrF) of service: 2018
- Yr1 Ridership: 62,400
- YrF Ridership: 62,400
- Length of Average Trip (L): 16 miles
- Vehicle Type: 2015 hybrid-diesel Over-Road Coach
- Annual VMT: 37,440 miles are estimated to operate the expanded service
- FY 2016-17 LCTOP funds requested: \$93,860
- No additional LCTOP GGRF funds requested
- No additional GGRF funds requested
- Where project specific data is not available, ARB defaults were used.

### Methods to apply

#### New/Expanded Service

$$\begin{aligned} \text{GHG Emission Reductions} = \\ \text{GHG Emission Reductions of Displaced Autos} \\ - \text{GHG Emissions of New/Expanded Service} \end{aligned}$$

<sup>4</sup> The hypothetical project has not undergone verification of any LCTOP Program requirements; all assumptions about location type and features are for quantification methodology demonstration purposes only.

## Step 1: Determine the LCTOP Project Inputs Needed from the Allocation Request

### General Information (Request Tab)

- Project Name: Expanded Commuter Express Service
- Lead Agency: Sacramento Transit
- Date Completed: 1/15/2017
- Project ID, if applicable: N/A
- Contact Name: John Smith
- Contact Phone Number: (916) 445-4623
- Contact Email: [john.smith@sactransit.org](mailto:john.smith@sactransit.org)
- Date Completed: 1/15/2017
- Project Category: Operations: New/Expanded Service
- Project Type: Expand/Enhance transit service
- FY 16-17 LCTOP funds requested: \$93,860.00
- Total amount of LCTOP funds requested: \$93,860.00
- Total amount of GGRF funds requested: \$93,860.00

### Project Specific Inputs (Request Tab)

- Year 1 (Yr1): 2017
- Year (YrF): 2018
- Yr1 Ridership: 62,400
- YrF Ridership: 62,400
- Adjustment Factor (A): 0.83 (default)
- Length of Average Trip (L): 16

## Step 2: Identify the LCTOP Project Inputs Needed

### Greenhouse Gas Quantification Inputs (GHG Calculator Tab)

- Region: Air Basin
- Subregion: Sacramento Valley
- Service Type: Intercity/Express Bus (Long Distance)
- Vehicle Type: Over-Road Coach
- Hybrid Vehicle: Yes
- Fuel Type: Diesel (gal)
- Model year: 2015
- Annual VMT: 37,440

## Step 3: Estimate GHG Emission Reduction for the LCTOP Project using the GHG Calculator Tool

<b>Project Name:</b>	Expanded Commuter Express Service	<b>Contact Name:</b>	John Smith
<b>Lead Agency:</b>	Sacramento Transit	<b>Contact Phone #:</b>	(916) 445-4623
<b>Date Completed:</b>	1/15/2017	<b>Contact Email:</b>	john.smith@sactransit.org
<b>Project ID:</b>	To be filled out by Caltrans		

	Applicant must input if required		Calculated field; no input required
	Required input from Allocation Request Form		Applicant must submit additional documentation

Applicant must input required fields from top down (i.e., first Project Category, then Project Type, etc.).  
 Required fields and descriptions are dependent on the inputs selected or entered.  
 User tips to provide clarification or suggested inputs may appear when input cells are selected.

Inputs		Required	Description
This section is used to determine the GHG emission reduction method and emission factors to apply.			
<b>Project Category</b>	Operations: New/Expanded Service	Yes	Enter the project category that best represents the proposed project type; see <b>Required Fields by Category</b> . If applying for more than one project type, then the agency must submit multiple Allocation Requests and GHG Calculator tools.
<b>Project Type</b>	Expand/Enhance transit service	Yes	Expand/Enhance transit service (extend transit routes, extend service hours, increase frequency of service, increase capacity [e.g., add more buses or rail cars to existing routes]). <b>GHG Emission Reductions = GHG Emissions of Displaced Autos – GHG Emissions of New Service</b>
<b>Region</b>	Air Basin	Yes	The region that best encompasses the geographic location for the proposed project type.
<b>Subregion</b>	Sacramento Valley	Yes	The air basin where the majority of the service occurs.
<b>Year 1 (Yr1)</b>	2017	Yes	The first year of service - funded by FY 2016-17 LCTOP funds.
<b>Year F (YrF)</b>	2018	Yes	The final year of service - funded by FY 2016-17 LCTOP funds.
<b>Useful Life</b>	1	Calculated	The number of years the service is funded by FY 2016-17 LCTOP funds.
This section is used to estimate the GHG emissions from displaced auto vehicle miles traveled (VMT).			
<b>Service Type</b>	Intercity/Express Bus (Long Distance)	Yes	The transit service (e.g., Intercity/Express Bus (Long Distance), Light Rail, Vanpool, etc.) benefiting directly from the proposed project. For projects that benefit multiple services, select Multi-modal.
<b>Yr1 Ridership</b>	62,400	Yes	The increase in unlinked passenger trips directly associated with the proposed project in the first year.
<b>YrF Ridership</b>	62,400	Yes	The increase in unlinked passenger trips directly associated with the proposed project in the final year. If the ridership is not expected to change, the same value should be input for Yr1 and YrF.
<b>Adjustment Factor (A)</b>	0.83	Yes	Discount factor applied to annual ridership to account for transit-dependent riders. Use documented project specific data or system average developed from a recent, statistically valid survey or default.
<b>Length of Average Trip (L)</b>	16	Yes	Annual passenger miles over unlinked trips directly associated with the proposed project.
<b>GHG Emission Reductions</b>	427.08	Calculated	The estimated GHG emission reductions in metric ton (MT) of carbon dioxide equivalent (CO <sub>2</sub> e) from displaced auto VMT from the proposed project.
This section is used to estimate the net GHG emission reductions from new/expanded service or from the purchase of new zero-emission/hybrid vehicle(s).			
<b>Vehicle Type</b>	Over-Road Coach	Yes	The vehicle type (e.g., Transit Bus, Streetcar, Ferry, etc.) that will operate the new service.
<b>Hybrid Vehicle</b>	Yes	Yes	Is the vehicle that will operate the new service a hybrid?
<b>Fuel Type</b>	Diesel (gal)	Yes	The fuel type (e.g., Electric, Diesel, etc.) of the vehicle that will operate the new service.
<b>Project Specific Emission Factor</b>		Optional	Applicant must be able to demonstrate an approved carbon intensity value under the Low Carbon Fuel Standard or a verifiable grid-emission factor; must submit additional documentation.
<b>Model Year</b>	2015	Yes	The engine model year of the vehicle that will operate the new service.
<b>Annual VMT</b>	37,440	Yes	The estimated annual VMT required to operate the new service (e.g., 72,000). For rail and ferry vehicles, applicants may alternatively use Annual Fuel.
<b>Annual Fuel</b>		No	Not applicable for this vehicle type.
<b>GHG Emissions</b>	68.68	Calculated	The estimated GHG emissions (MTCO <sub>2</sub> e) of the vehicle that will operate the new service.
<b>Net GHG Benefit</b>	357.40	Calculated	The estimated net GHG emission reductions (MTCO <sub>2</sub> e) of the new service.
This section is used to estimate the net GHG emission reductions from vehicle replacement or the GHG emission reductions from displaced fuel.			
<b>Additional Benefits: Displaced GHG Emissions</b>	Not Applicable	Yes	Not applicable for this project type.
This section is used to gather the total Greenhouse Gas Reduction Fund (GGRF) funding requested or awarded.			
<b>FY 2016-17 LCTOP Funds Requested</b>	\$93,860.00	Yes	The amount of FY 2016-17 LCTOP dollars the applicant is requesting from Caltrans per State Controller's Office Eligible list for FY 2016-17.
<b>Total LCTOP GGRF Funds Requested</b>	\$93,860.00	Yes	The amount equal to FY 2016-17 LCTOP Funds Requested plus all LCTOP dollars from Caltrans that have previously been awarded to the same project and any future LCTOP dollars that the project plans to apply for. If no other LCTOP funds have been requested, the Total LCTOP Funds Requested (\$) will be the same amount as the FY 2016-17 LCTOP Funds Requested.
<b>Total GGRF Funds Requested</b>	\$93,860.00	Yes	The amount equal to the Total LCTOP Funds Requested plus all GGRF dollars that have previously been awarded to the same project and any other GGRF dollars that the project has or plans to apply for. If no other GGRF funds have been requested, the Total GGRF Funds Requested (\$) will be the same amount as the Total LCTOP GGRF Funds Requested.
This section calculates the greenhouse gas (GHG) emission reductions achieved by the proposed project.			
<b>Total Project GHG Reductions</b>	357.40	Calculated	Total GHG emission reductions (MTCO <sub>2</sub> e) from the project during the useful life.
<b>LCTOP Project GHG Reductions</b>	357.40	Calculated	The prorated Total Project GHG Reductions based on the Total LCTOP GGRF funds over Total GGRF funds requested.

## Appendix B. Equations Supporting the LCTOP GHG Calculator Tool

The GHG emission reductions from the project are quantified within the LCTOP GHG Calculator Tool using the equations below. The GHG emission reductions are quantified using the equations below for Year 1 and Year F.

### A. GHG Emission Reductions from Capital/Service Improvements

The GHG emission reductions from Capital/Service Improvements projects that result in an increase in ridership are calculated as the GHG emission reductions from displaced autos. Equation 1 is used to calculate the annual VMT reductions from the proposed project and Equation 2 is used to calculate the GHG emission reductions associated with auto VMT reductions.

#### Displaced Autos

$$\text{GHG Emission Reductions} = \text{GHG Emission Reductions of Displaced Autos}$$

#### Equation 1: Annual Auto VMT Reduced in Miles per Year

$$\text{AutoVMT} = [(R) * (A) * (L)]$$

Where,		Units
R	= Increase in unlinked passenger trips directly associated with the proposed project	Annual Riders
A	= Adjustment factor to account for transit dependency	Unitless
L	= Passenger-miles divided by unlinked trips directly associated with the proposed project.	Rider-miles

#### Equation 2: GHG Emission Reductions of Displaced Autos

$$\text{GHG Emissions of Displaced Autos} = \frac{[(\text{AutoVMT}) * (\text{AVEF})]}{1,000,000}$$

Where,		Units
AutoVMT	= Annual auto VMT reduced (see Equation 1)	Miles
AVEF	= Auto Vehicle Emission Factor; see Table C-1	gCO <sub>2</sub> e/mile
1,000,000	= Conversion factor	Grams/MT

## B. GHG Emission Reductions from New/Expanded Service

The GHG emission reductions from New/Expanded Service projects are calculated as the difference between the GHG emission reductions from displaced autos and GHG emissions from the new service calculated using Equation 3.

### New/Expanded Service

$$\begin{aligned} \text{GHG Emission Reductions} = \\ \text{GHG Emission Reductions of Displaced Autos} \\ - \text{GHG Emissions of New/Expanded Service} \end{aligned}$$

### Equation 3: GHG Emission Reductions from New/Expanded Service

$$\text{GHG Emissions of New/Expanded Service} = \frac{[(NSVMT) * (NSEF)]}{1,000,000}$$

Or (for train/ferry service use only)

$$= \frac{[(NSFuel) * (FuelEF)]}{1,000,000}$$

Where,			<u>Units</u>
<i>NSVMT</i>	=	The estimated annual VMT required to operate the new service	Miles
<i>NSEF</i>	=	Emission factor based on service type; see Table C-1	gCO <sub>2</sub> e/mile
<i>NSFuel</i>	=	The estimated annual fuel required to operate the new service- only available for train and ferry services	unit of fuel
<i>FuelEF</i>	=	Emission factor based on fuel type; see Table C-2	gCO <sub>2</sub> e/ unit of fuel
<i>1,000,000</i>	=	Conversion factor	Grams/MT

## C. GHG Emission Reductions from Cleaner Vehicles

The GHG emission reductions from the acquisition of Cleaner Vehicles are calculated as the difference between the displaced baseline vehicle emissions and new vehicle emissions. GHG emissions from both the displaced and new vehicle are calculated using Equation 4.

### Cleaner Vehicles

$$\begin{aligned} \text{GHG Emission Reductions} = \\ \text{GHG Emission Reductions of Displaced Vehicle} - \text{GHG Emissions of New Vehicle} \end{aligned}$$

**Equation 4: GHG Emission Reductions from Cleaner Vehicles**

$$GHG \text{ Emissions of Displaced/New Vehicle} = \frac{[(AnnualVMT) * (VehicleEF)]}{1,000,000}$$

Or

$$GHG \text{ Emissions of Displaced/New Vehicle} = \frac{[(AnnualFuel) * (FuelEF)]}{1,000,000}$$

Where,		<u>Units</u>
<i>AnnualVMT</i>	= The estimated annual VMT of the vehicle to be acquired	Miles
<i>VehicleEF</i>	= Emission factor based on vehicle type; see Table C-1	gCO <sub>2</sub> e/mile
<i>AnnualFuel</i>	= The estimated annual fuel of the vehicle to be acquired - only available for train and ferry services	unit of fuel
<i>FuelEF</i>	= Emission factor based on fuel type; see Table C-2	gCO <sub>2</sub> e/unit of fuel
<i>1,000,000</i>	= Conversion factor	Grams/MT

**D. GHG Emission Reductions from Displaced Fuel**

The GHG emission reductions from Displaced Fuel are calculated using Equation 5.

**Displaced Fuel**

$$GHG \text{ Emission Reductions} = GHG \text{ Emission Reductions of Displaced Fuel}$$

**Equation 5: GHG Emission Reductions from New Service**

$$GHG \text{ Emissions of Displaced Fuel} = \frac{[(AnnualFuel) * (FuelEF)]}{1,000,000}$$

Where,		<u>Units</u>
<i>AnnualFuel</i>	= The estimated annual displaced fuel to be realized as a result of the project	unit of fuel
<i>FuelEF</i>	= Emission factor based on fuel type; see Table C-2	gCO <sub>2</sub> e/ unit of fuel
<i>1,000,000</i>	= Conversion factor	Grams/MT

## Appendix C. Emission Factors

### Emission Factor Lookup Tables

GGRF programs estimate transportation-related emissions using a “Well-to-Wheels” approach, which consists of emissions resulting from the production and distribution of different fuel types and any associated exhaust emissions. LCTOP applicants use project-specific data to calculate new or avoided vehicle miles traveled (VMT) and VMT is converted to greenhouse gas emissions using Well-to-Wheels emission factors embedded in the LCTOP GHG Calculator Tool. Table C-1 provides links to the relevant Lookup tables used in the LCTOP GHG calculator. A detailed methodology of how the emission factors were developed is provided below.

**Table C-1. Emission Factor Look Up Tables**

Vehicle Type	Link to Emission Factor Lookup Tables
Auto	<a href="https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/ef_autos_draft.pdf">https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/ef_autos_draft.pdf</a>
Cut-A-Way	<a href="https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/ef_cutaway_draft.pdf">https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/ef_cutaway_draft.pdf</a>
Over-Road Coach	<a href="https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/ef_mc_draft.pdf">https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/ef_mc_draft.pdf</a>
Train*	<a href="https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/ef_train_draft.pdf">https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/ef_train_draft.pdf</a>
Transit Bus	<a href="https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/ef_ubus_draft.pdf">https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/ef_ubus_draft.pdf</a>
Van	<a href="https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/ef_van_draft.pdf">https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/ef_van_draft.pdf</a>

\*Train lookup tables include Heavy Rail, Light Rail and Streetcar emission factors.

### Ferry Emission Factors

Due to the high variability in ferries, standardized emission factors are not available for new ferry service. Emissions for ferries require project-specific information for the estimated quantity and type of fuel used annually, which are used with the appropriate carbon content factor from Table C-2 to convert fuel to GHG emissions. The same emission factor will be used for both Year 1 and Year F.

### Train Emission Factors

Due to the high variability in trains, applicants may use project-specific information on the estimated quantity and type of fuel used annually, which are used with the appropriate carbon content factor from Table C-2 to convert fuel to GHG emissions. The same emission factor will be used for both Year 1 and Year F.



**Table C-2. Fuel-Specific Factors**

<b>Fuels (units)</b>	<b>Energy Density</b>	<b>Carbon Intensity</b>	<b>Carbon Content*</b>
Biodiesel (gal)	126.13 (MJ/gal)	65.50 (gCO <sub>2</sub> /MJ)	8,261.64 (gCO <sub>2</sub> e/gal)
CNG (ft <sup>3</sup> )	1.04 (MJ/ft <sup>3</sup> )	78.37 (gCO <sub>2</sub> /MJ)	81.28 (gCO <sub>2</sub> e/ft <sup>3</sup> )
Diesel (gal)	134.48 (MJ/gal)	102.01 (gCO <sub>2</sub> /MJ)	13,718.04 (gCO <sub>2</sub> e/gal)
Electric (KWh)	3.60 (MJ/KWh)	105.15 (gCO <sub>2</sub> /MJ)	378.54 (gCO <sub>2</sub> e/KWh)
Gas (gal)	115.83 (MJ/gal)	98.47 (gCO <sub>2</sub> /MJ)	11,405.84 (gCO <sub>2</sub> e/gal)
Hydrogen (kg)	119.99(MJ/kg)	88.33 (gCO <sub>2</sub> /MJ)	10,598.43 (gCO <sub>2</sub> e/kg)
LNG (gal)	78.83 (MJ/gal)	94.41 (gCO <sub>2</sub> /MJ)	7,442.70 (gCO <sub>2</sub> e/gal)
Renewable Diesel (gal)	129.65 (MJ/gal)	43.31 (gCO <sub>2</sub> /MJ)	5,615.12 (gCO <sub>2</sub> e/gal)
Renewable Natural Gas (ft <sup>3</sup> )	1.04 (MJ/ft <sup>3</sup> )	18.11 (gCO <sub>2</sub> /MJ)	18.78 (gCO <sub>2</sub> e/ft <sup>3</sup> )

\*Carbon Content Emission Factors are calculated using fuel type Energy Density (megajoule (MJ) per unit of fuel) and the fuel type Carbon Intensity (grams of CO<sub>2</sub>e per MJ).

**Table C-3. Energy Economy Ratios**

<b>Fuels (units)</b>	<b>EER Values Relative to Diesel</b>	<b>EER Values Relative to Gas</b>
Biodiesel (gal)	1.0	--
CNG (ft <sup>3</sup> )	0.9	1.0
Diesel (gal)	1.0	--
Electric (KWh)	4.2 (Bus) 4.6 (Heavy Rail) 3.3 (Light Rail) 3.1 (Street Car)	3.4
Gas (gal)	0.9	1.0
Hydrogen (kg)	1.9	2.5
LNG (gal)	0.9	1.0
Renewable Diesel (gal)	1.0	--
Renewable Natural Gas (ft <sup>3</sup> )	0.9	1.0

The following sections detail how the emission factors were developed.



The emission factors were developed using fuel consumption rates from ARB's Mobile Source Emission Factor Model (EMFAC 2014) and carbon intensity values for different fuel types from ARB's Low Carbon Fuel Standard (LCFS) Program. This approach provides consistency amongst transportation-related GGRF programs and ARB's Low Carbon Fuel Standard (LCFS) Program.

## Auto Vehicle Emission Factors

Passenger (auto) vehicle emission factors (**AVEF**) were derived using the following steps.

1. Emissions by county for each calendar year from 2017 through 2050 were downloaded from EMFAC 2014 with the following parameters:
  - a. Annual Average
  - b. EMFAC2011 vehicle categories LDA, LDT1, LDT2, and MDV
  - c. Aggregated model year
  - d. Aggregated speed
  - e. Gasoline fuel
2. The auto fuel consumption rate (**AFCR**, in gallons of gasoline per mile) was calculated using the total gallons of gasoline used by each vehicle category divided by the total mileage by vehicle category by county and year, using the following equation:

$$AFCR = \frac{(Fuel\_Consumption_{LDA} + Fuel\_Consumption_{LDT1} + Fuel\_Consumption_{LDT2} + Fuel\_Consumption_{MDV}) * 1,000}{VMT_{LDA} + VMT_{LDT1} + VMT_{LDT2} + VMT_{MDV}}$$

Where:

**Fuel\_Consumption:** the total fuel consumption for the vehicle type, in 1,000 gallons per day, from EMFAC 2014

**VMT:** is the total vehicle miles traveled for the vehicle type, in miles per day, from EMFAC 2014.

3. The auto vehicle emission factors (**AVEF**, in grams of CO<sub>2</sub>e per mile) were calculated for each year and county by multiplying the auto fuel consumption rate by the Well-to-Wheels carbon content factor for gasoline, which is 11,405.84 g CO<sub>2</sub>e per gallon (Table C-2), using the following equation:

$$AVEF = 11,405.84 * AFCR$$

## Transit Bus and Over-Road Coach Emission Factors

The transit bus/over-road coach (bus) emission factors (**BEF**) were derived using a similar method, as follows.

1. The statewide emissions each calendar year from 2017 through 2050 were downloaded from EMFAC 2014 with the following parameters:
  - a. Annual Average
  - b. EMFAC2011 vehicle categories UBUS for Transit Bus and Motor Coach (MC) for Over-Road Coach
  - c. All model years
  - d. Aggregated speed
  - e. Diesel fuel
2. The bus fuel consumption rate (**BCR**, in gallons of diesel per mile) was calculated using the total gallons of diesel fuel used by each vehicle category and model year divided by the total mileage by vehicle category and model year, using the following equation:

$$BCR_{diesel} = \frac{Fuel\_Consumption_{(UBUS \text{ OR } MC)} * 1,000}{VMT_{(UBUS \text{ OR } MC)}}$$

3. Diesel emission factors were developed using data as described in (a) below. Emission factors for other fuel types convert the diesel bus fuel consumption rate to the appropriate fuel type as described in (b).
  - a. Diesel: the bus emission factor (**BEF**, in grams of CO<sub>2</sub>e per mile) for each calendar year and model year were obtained by multiplying the bus fuel consumption rate (**BCR**, in gallons per mile) by the Well-to-Wheels carbon content factor for diesel (13,718.04 g CO<sub>2</sub>e per gallon) using the following equation:

$$BEF = 13,718.04 * BCR$$

- b. Non-Diesel: For fuel types other than diesel, staff converted the diesel fuel consumption rate (**BCR**) from Step 2 to the equivalent bus emission factor (**BEF**, in grams of CO<sub>2</sub>e per mile) using the following equation:

$$BEF_{new\_fuel} = BCR_{diesel} * ED_{diesel} * \left( \frac{1}{ED_{new\_fuel}} \right) * \left( \frac{1}{EER} \right) * CC_{new\_fuel}$$

Where:

<b>BCR<sub>diesel</sub></b>	= Bus Consumption Rate for diesel, from Step 2 (gallons per mile)
<b>ED<sub>diesel</sub></b>	= 134.48 MJ per gallon, from Table C-2
<b>ED<sub>new fuel</sub></b>	= Energy density of the new fuel type (MJ per unit of new fuel), from Table C-2
<b>EER</b>	= Energy Economy Ratio (unitless), from Table C-3
<b>CC<sub>new_fuel</sub></b>	= Carbon Content of the new fuel type (grams of CO <sub>2</sub> e per unit of new fuel), from Table C-2

## Cut-A-Way and Van Emission Factors

The alternative transit vehicle emission factors (**ATEF**) were derived using a similar method, as follows.

1. The statewide emissions each calendar year from 2017 through 2050 were downloaded from EMFAC 2014 with the following parameters:
  - a. Annual Average
  - b. EMFAC2011 vehicle categories LDH1 for Van and LHD2 for Cut-A-Way
  - c. All model years
  - d. Aggregated speed
  - e. Gasoline fuel
2. The alternative transit vehicle fuel consumption rate (**ATCR**, in gallons of gasoline per mile) was calculated using the total gallons of gasoline fuel used by each vehicle category and model year divided by the total mileage by vehicle category and model year, using the following equation:

$$ATCR_{gasoline} = \frac{Fuel\_Consumption_{(LDH1 \text{ OR } LDH2)} * 1,000}{VMT_{(LDH1 \text{ OR } LDH2)}}$$

3. Gasoline emission factors were developed using data as described in (a) below. Emission factors for other fuel types convert the gasoline alternative transit vehicle fuel consumption rate to the appropriate fuel type as described in (b or c).
  - a. Gasoline: the alternative transit vehicle emission factor (**ATEF**, in grams of CO<sub>2</sub>e per mile) for each calendar year and model year were obtained by multiplying the alternative transit vehicle fuel consumption rate (**ATCR**, in gallons per mile) by the Well-to-Wheels carbon content factor for gasoline (11,405.84 g CO<sub>2</sub>e per gallon) using the following equation:

$$ATEF = 11,405.84 * ATCR$$

- b. Non-Gasoline (non-diesel): For non-diesel fuel types other than gasoline, staff converted the gasoline fuel consumption rate (**ATCR**) from Step 2 to the equivalent alternative transit vehicle emission factor (**ATEF**, in grams of CO<sub>2</sub>e per mile) using the following equation:

$$ATEF_{new\_fuel} = ATCR_{gas} * ED_{gas} * \left( \frac{1}{ED_{new\_fuel}} \right) * \left( \frac{1}{EER} \right) * CC_{new\_fuel}$$

Where:

<b>ATCR<sub>gas</sub></b>	= Alternative Transit Vehicle Consumption Rate for gasoline, from Step 2 (gallons per mile)
<b>ED<sub>gas</sub></b>	= 115.83 MJ per gallon, from Table C-2
<b>ED<sub>new fuel</sub></b>	= Energy density of the new fuel type (MJ per unit of new fuel), from Table C-2
<b>EER</b>	= Energy Economy Ratio (unitless), from Table C-3
<b>CC<sub>new_fuel</sub></b>	= Carbon Content of the new fuel type (grams of CO <sub>2</sub> e per unit of new fuel), from Table C-2

- c. Non-Gasoline (diesel): For diesel, staff converted the gasoline fuel consumption rate (**ATCR**) from Step 2 to the equivalent alternative transit vehicle emission factor (**ATEF**, in grams of CO<sub>2</sub>e per mile) using the following equation:

$$ATEF_{diesel} = ATCR_{gas} * EER * ED_{gas} * \left( \frac{1}{ED_{diesel}} \right) * CC_{diesel}$$

Where:

<b>ATCR<sub>gas</sub></b>	= Alternative Transit Vehicle Consumption Rate for gasoline, from Step 2 (gallons per mile)
<b>EER</b>	= Energy Economy Ratio (unitless), from Table C-3
<b>ED<sub>gas</sub></b>	= 115.83 MJ per gallon, from Table C-2
<b>ED<sub>diesel</sub></b>	= 134.47 MJ per gallon, from Table C-2
<b>CC<sub>diesel</sub></b>	= Carbon Content of diesel (grams of CO <sub>2</sub> e per gallon), from Table C-2

## Train Emission Factors

Train emission factors were derived using the following process.

1. A Train Consumption Rate (**TCR**, in gallons of diesel per mile) was calculated using the total gallons of diesel fuel used by 130 trains across the State in 2010 divided by the total mileage of those trains using the following equation:

$$TCR_{diesel} = \frac{Fuel\ Consumption}{VMT}$$

2. The diesel emission factor was developed using data as described in (a) below. Emission factors for other fuel types convert the diesel new service fuel consumption rate to the appropriate fuel type as described in (b).
  - a. Diesel: the train emission factor (**TEF**, in grams of CO<sub>2</sub>e per mile) was obtained by multiplying the train fuel consumption rate (**TCR**, in gallons per mile) by the Well-to-Wheels carbon content factor for diesel (13,718.04 g CO<sub>2</sub>e per gallon) using the following equation:

$$TDEF = 13,718.04 * TCR$$

- b. Non-Diesel: For fuel types other than diesel, staff converted the diesel fuel consumption rate (**TCR**) from Step 2 to the equivalent new service emission factor (**TEF**, in grams of CO<sub>2</sub>e per mile) using the following equation:

$$TEF_{new\_fuel} = TCR_{diesel} * ED_{diesel} * \left( \frac{1}{ED_{new\_fuel}} \right) * \left( \frac{1}{EER} \right) * CC_{new\_fuel}$$

Where:

**TCR<sub>diesel</sub>** = Train Consumption Rate for diesel (gallons per mile)

**ED<sub>diesel</sub>** = 134.48 MJ per gallon, from Table C-2

**ED<sub>new fuel</sub>** = Energy density of the new fuel type (MJ per unit of new fuel), from Table C-2

**EER** = Energy Economy Ratio (unitless), from Table C-3

**CC<sub>new fuel</sub>** = Carbon Content of the new fuel type (grams of CO<sub>2</sub>e per unit of new fuel), from Table C-2